# Effect of multiple jet passes treatment in waterjet peening on fatigue performance

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# Content of presentation

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# Overview

The present work is a continuation from the previous work of the same authors.

Azhari, A. et al.: Improving surface hardness of austenitic stainless steel using waterjet peening process. The International Journal of Advanced Manufacturing Technology, 63 (2012), pp. 1035-1046.

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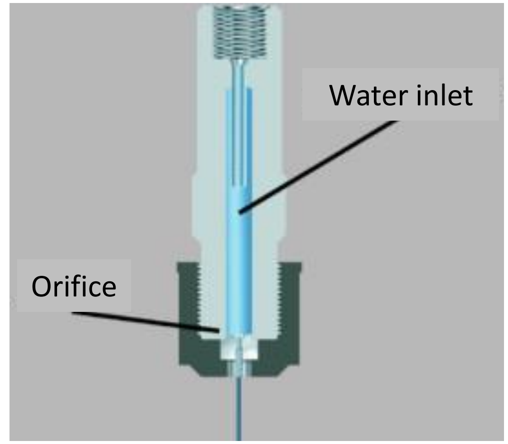
# Introduction

Water is normally compressed up to about 600 MPa and discharged from a small orifice [2].

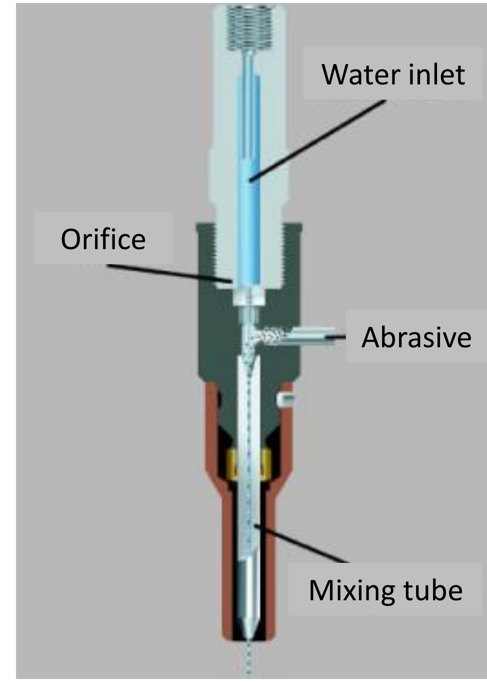
Waterjet technology

Started in early 1960s [1].

Applications:
-machining - cleaning
- coating removal - peening (WJP)
-etc.



Pure waterjet [3]



Abrasive waterjet [3]


[1] FOLKES, J.: Waterjet—An innovative tool for manufacturing. Journal of Materials Processing Technology, 209 (2009), pp. 6181-6189.
[2] HASHISH, M.: Pressure effects in abrasive-waterjet (AWJ) machining. Journal of Engineering Materials and Technology, 111 (1989), pp. 221-228.
[3] OLSEN, C. Basic waterjet principle, URL: www.waterjets.org (Accessed on 02/12/2013)

# Introduction (cont.)

High impact water drops on the surface causing local plastic deformation

High compressive residual stresses are induced leading to enhanced fatigue life [5]

Waterjet peening (WJP)

A new mechanical surface strengthening process [4]

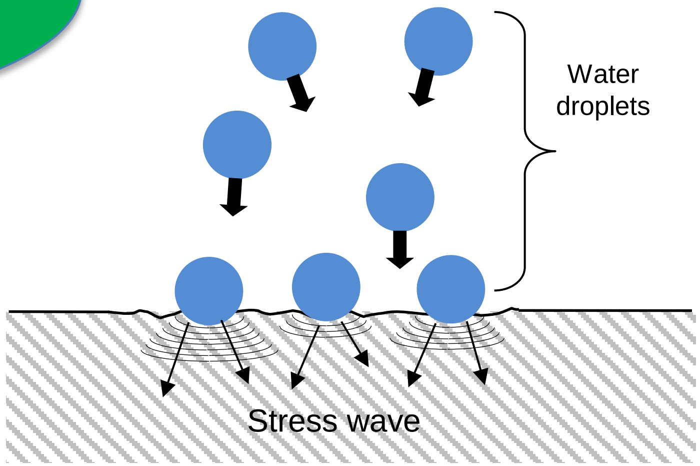



Illustration of WJP process

[4] TÖNSHOFF, H.K. et al.: High-pressure water peening-a new mechanical surface-strengthening process. CIRP Annals-Manufacturing Technology, 46 (1997), pp. 113-116.
[5] AROLA, D. et al.: Improving fatigue strength of metals using abrasive waterjet peening. Machining science and technology, 10 (2006), pp. 197-218.

# Motivation

Research on WJP has started about two decades ago [4].

Mechanical surface treatments

Other peening processes (e.g. shot peening (SP), and laser shock peening (LSP)) are more established.

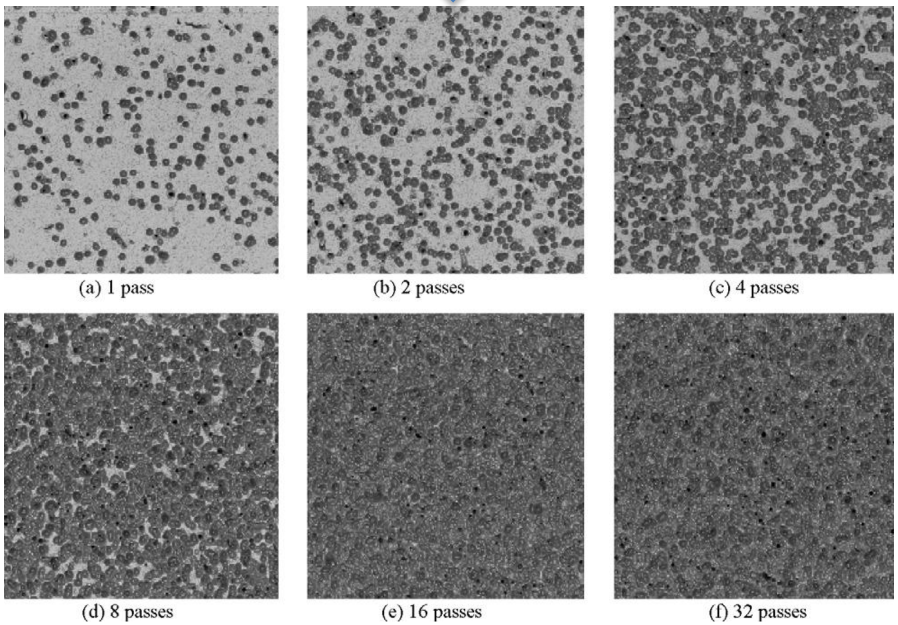
Still, a detailed knowledge is not comprehensively reported.

Also, all the works reported in literatures were carried out in a single-pass treatment.

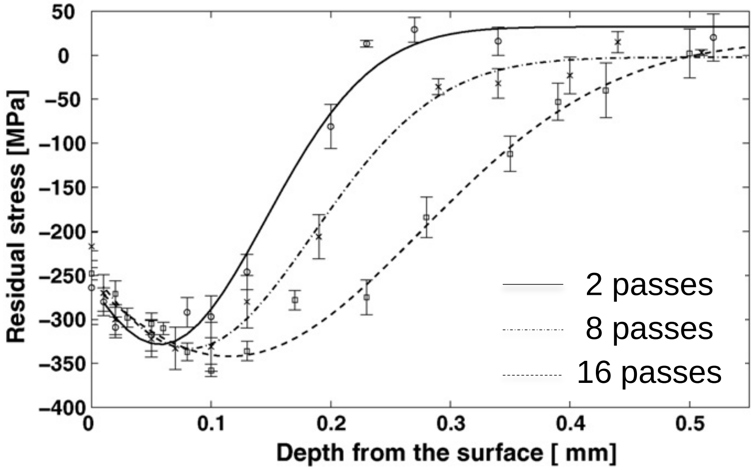
[4] TÖNSHOFF, H.K. et al.: High-pressure water peening - a new mechanical surface-strengthening process. CIRP Annals-Manufacturing Technology, 46 (1997), pp. 113-116.

# Motivation (cont.)

In shot peening, multiple shot peening passes resulted in larger surface roughness and coverage [8].




Also, more number of passes increased the maximum compressive residual stress as well as the thickness of the strengthening layer [8].



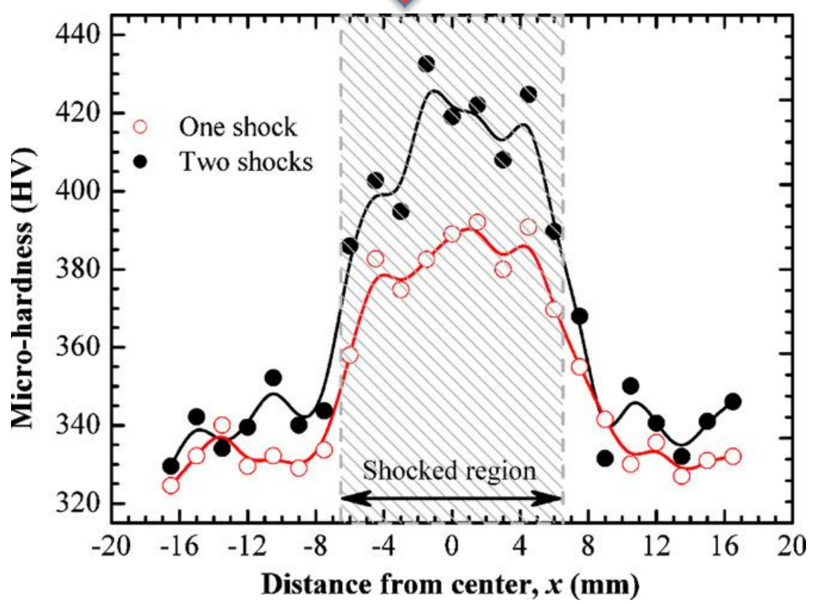


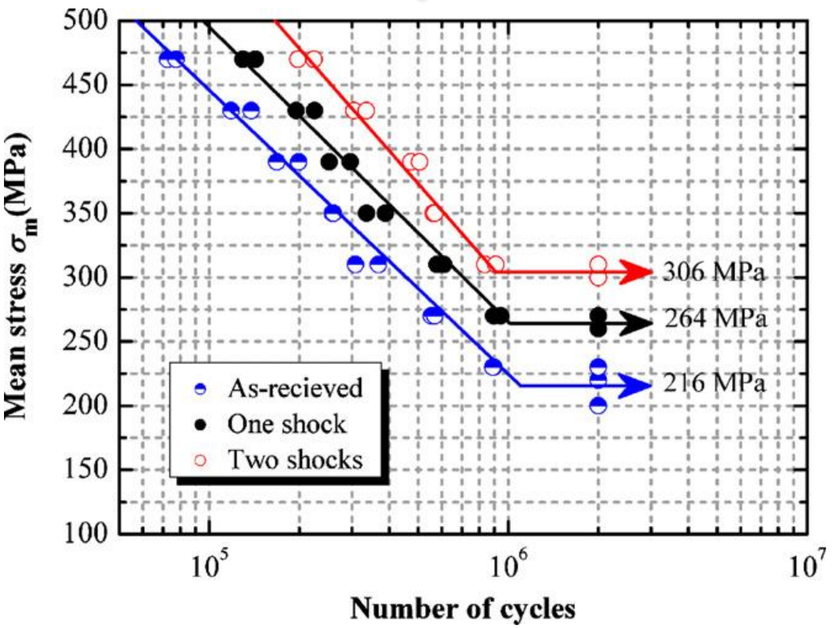
[8] MIAO, H. et al.: Experimental study of shot peening and stress peen forming. Journal of Materials Processing Technology, (2010), pp. 2089-2102.

# Motivation (cont.)

In LSP, using multiple laser shocks resulted in an increase in the hardness and magnitude of the residual stress [9].

Also, the fatigue life of the laser peened specimen with multiple laser shocks was higher [9].



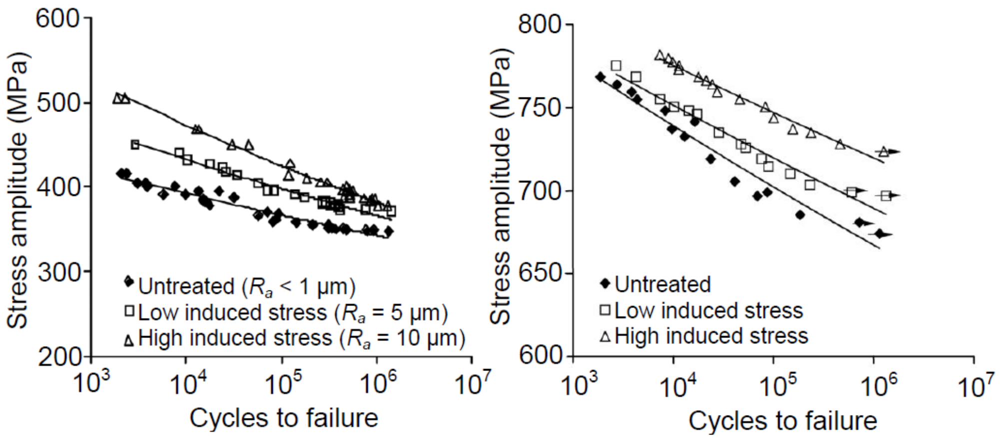

[9] LU, J.Z. et al., Grain refinement mechanism of multiple laser shock processing impacts on ANSI 304 stainless steel, Acta Materialia 58 (2010), 5354-5362.

# Motivation (cont.)

**Therefore, it is interesting to investigate the effect of multiple passes treatment in waterjet peening on fatigue performance of metals.**

# Literature Reviews

Arola et al. [10] reported the improvement of fatigue strength in abrasive waterjet peening of stainless steel 304 and titanium alloy Ti6Al4V. They found a rather limited increase in the fatigue strength for both materials (< 10 %).




Kunaporn et al. [11] reported a maximum increase in the fatigue strength by 20-30 % in waterjet peening of aluminium alloy 7075-T6.

During oil jet peening of carbon steel 1040, an improvement of fatigue strength by about 19 % was reported Grinspan [12].

# Literature Reviews (cont.)

Han et al. [13] reported an increase of fatigue life of about 15-20 % in water cavitation peening of carbon steel 1045. They also noticed that the improvement of fatigue life was obviously apparent at higher cycles.

The fatigue strength of stainless steel 316 under cavitating jets in air (CJA) and water (CJW) has been investigated by Soyama [14]. The cavitation peening in water takes place inside a water-filled chamber. It was found that the improvement of the fatigue strength using the cavitating jet is better in air than in water.


[10] AROLA, D.; ALADE, A.E.; WEBER, W.: IMPROVING FATIGUE STRENGTH OF METALS USING ABRASIVE WATERJET PEENING. MACHINING SCIENCE AND TECHNOLOGY, 10 (2006), PP. 197-218.

[11] KUNAPORN, S.; RAMULU, M.; JENKINS, M.; HASHISH, M.; HOPKINS, J.: ULTRA HIGH PRESSURE WATERJET PEENING, PART II: HIGH CYCLE FATIGUE PERFORMANCE. PROCEEDINGS OF WJTA AMERICAN WATERJET CONFERENCE, (2001), MINNESOTA, PAPER 26.

[12] GRINSPAN, A.S.; GNANAMOORTHY, R.: EFFECT OF OIL JET PEENING DURATION ON SURFACE MODIFICATION AND FATIGUE BEHAVIOR OF MEDIUM CARBON STEEL AISI 1040. MATERIALS SCIENCE AND ENGINEERING: A, 456 (2007), PP. 210-217.

[13] HAN, B.; JU, D.Y.; JIA, W.P.: INFLUENCE OF WATER CAVITATION PEENING WITH AERATION ON FATIGUE BEHAVIOUR OF SAE1045 STEEL. APPLIED SURFACE SCIENCE, 253 (2007), PP. 9342-9346.

[14] SOYAMA, H.: IMPROVEMENT OF FATIGUE STRENGTH BY USING CAVITATING JETS IN AIR AND WATER. JOURNAL OF MATERIALS SCIENCE, 42 (2007), PP. 6638-6641.

# Methodology

Materials:
-Stainless Steel 304
(DIN 1.4301)

Equipment:
UHDE Waterjet
machine

Methodology

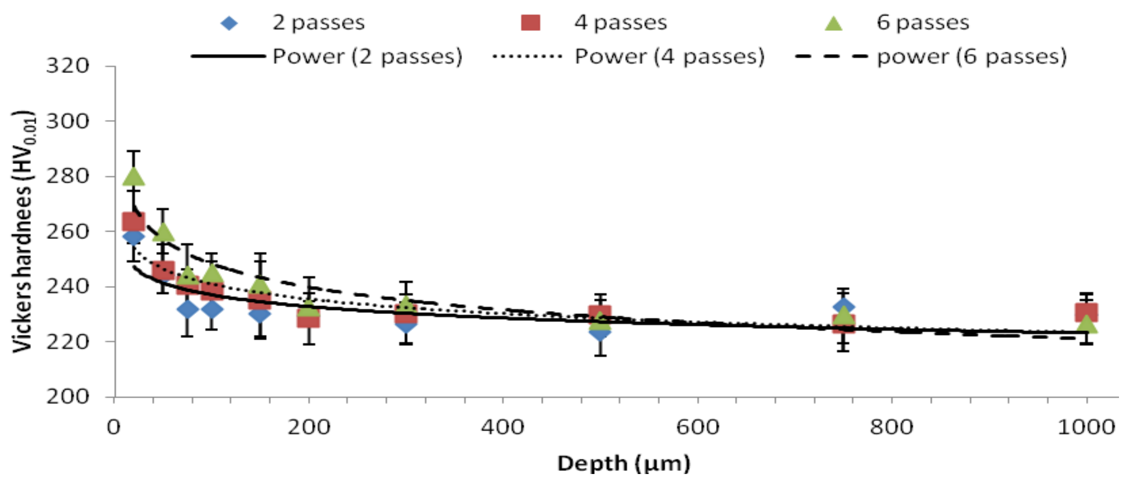
Responses:
- Roughness
- Erosion
- Microstructures
- Hardness
- Fatigue life

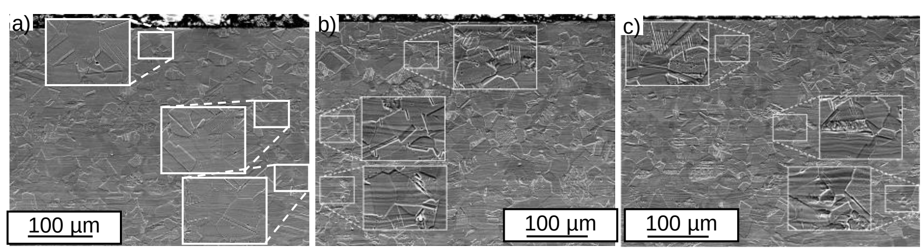
| Parameters | Ranges |
|---|---|
| Number of jet passes | 2 – 6 passes |

# Results and discussions

**Effect of peening parameters on hardness & microstructures**

The treated specimens showed an increase in surface hardness between 12 to 22% with respect to the base material [15].




Subsurface microstructures, a) 2 passes, b) 4 passes, c) 6 passess

[15] AZHARI, A. et al.: Improving surface hardness of austenitic stainless steel using waterjet peening process. The International Journal of Advanced Manufacturing Technology, 63 (2012), pp. 1035-1046.

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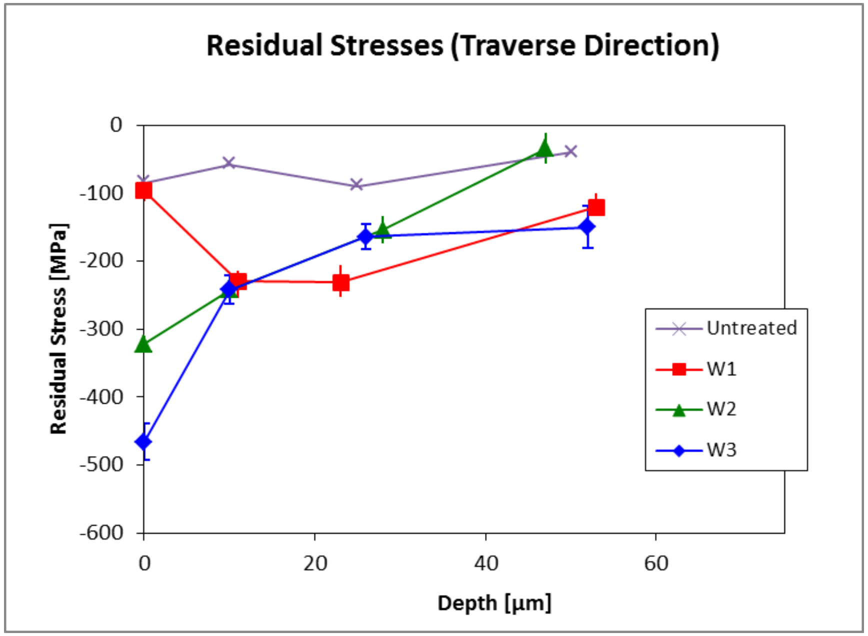
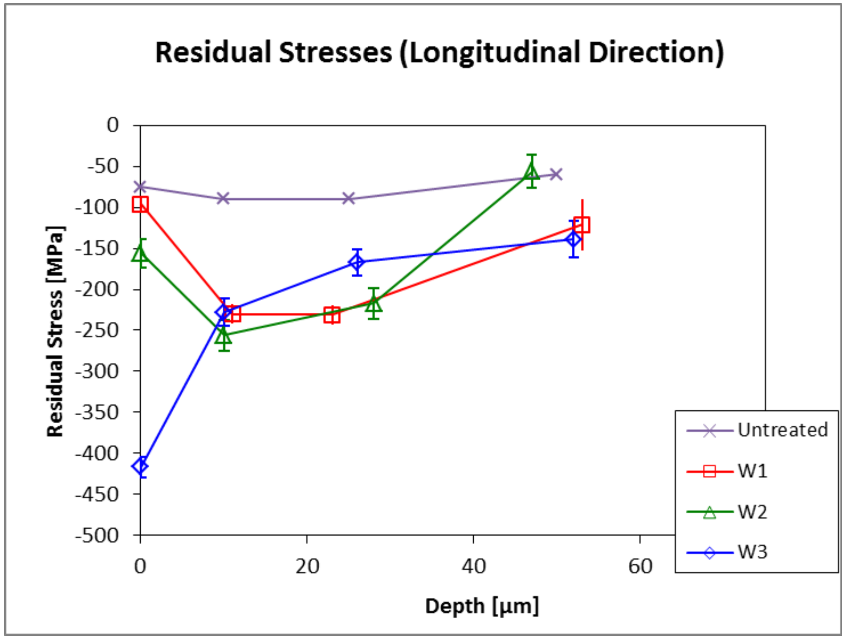
# Results and discussions

**Effect of peening parameters on residual stresses**

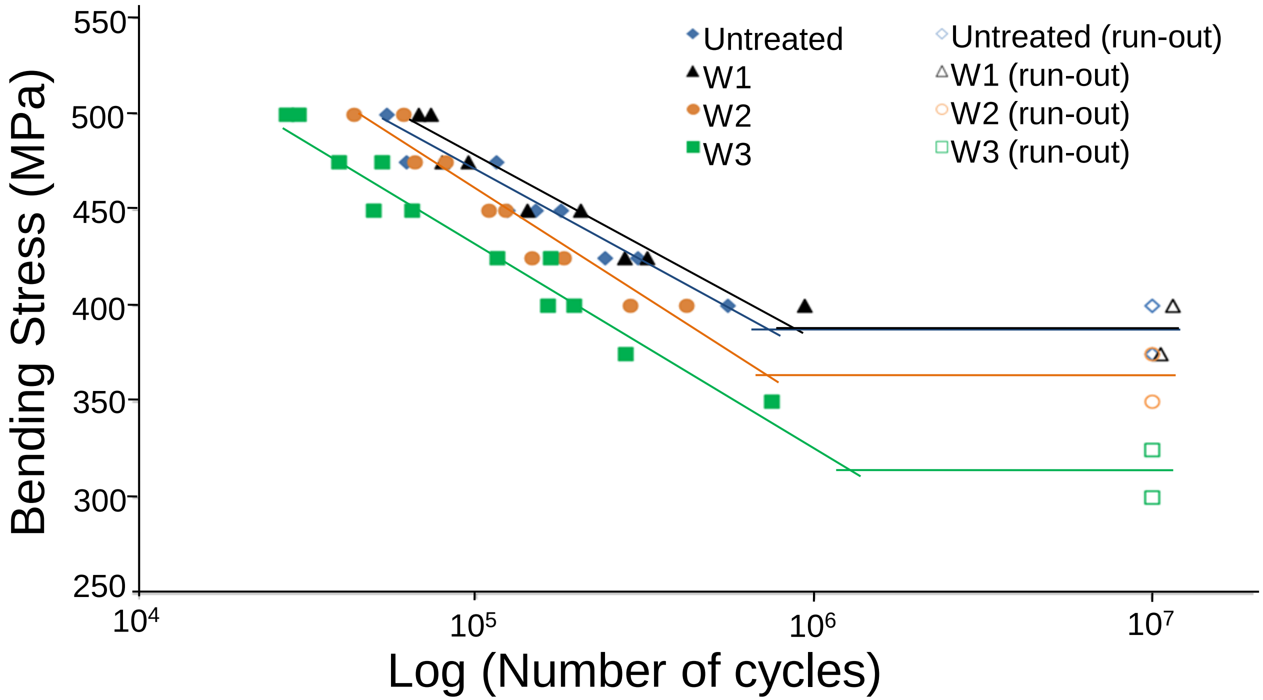
The introduction of compressive residual stresses in the treated specimens were observed between 56 to 417 MPa. However, the strengthening layer is limited within 50 µm below the surface .



# Results and discussions

**Effect of peening parameters on fatigue life**

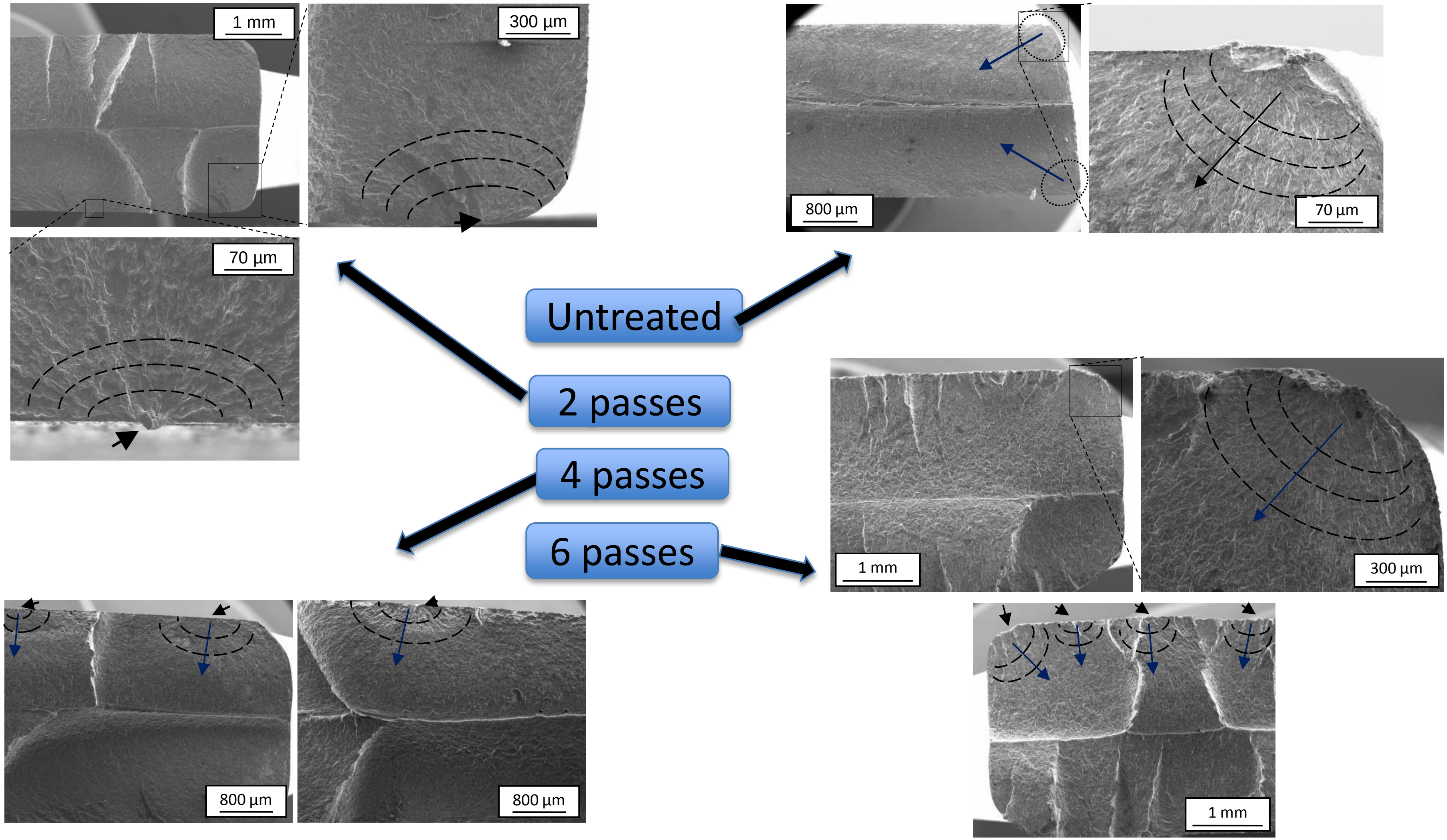



All waterjet treated specimens had shown lower fatigue strength than the original specimens.

Specimens with the highest increase in hardness as well as surface roughness resulted in the largest decrease in the fatigue strength.

# Results and discussions

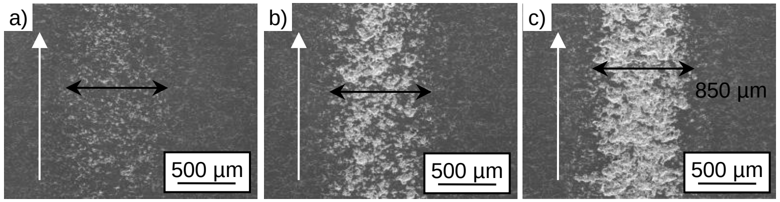
## Surface fracture analysis



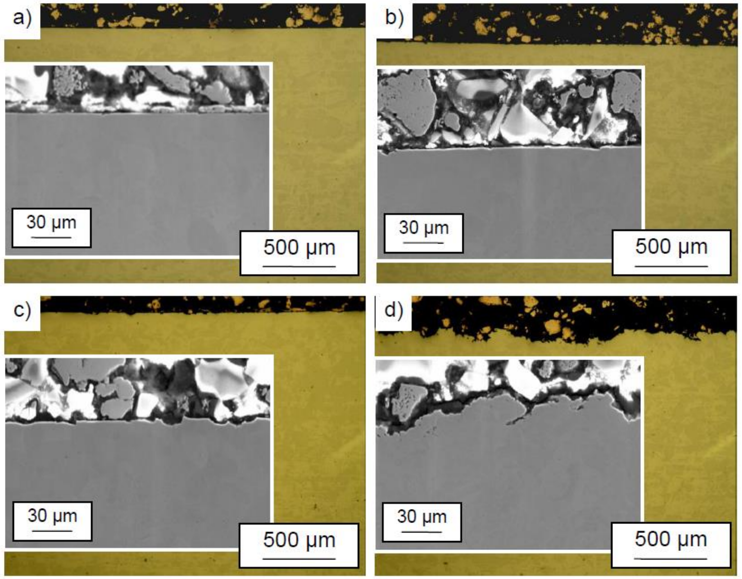
# Results and discussions

## Treated surface analysis

| Specimens | Surface roughness, Ra (µm) |
|---|---|
| Original | 0.14 – 0.16 |
| W1 (2 passes) | 0.78 – 0.94 |
| W2 (4 passes) | 1.60 – 2.62 |
| W3 (6 passes) | 2.34 – 4.86 |



Erosion tracks for different no. of passes, a) 2, b) 4, and c) 6 passes




Rougher surfaces are expected to encourage fatigue crack initiation [16].

Although, specimen W3 had the highest increase in hardness and compressive residual stresses, they also produced the highest roughness and erosion.

Perhaps, this leads to overpeening effect [17].


[16] TAYLOR, D.; CLANCY, O.M.: The fatigue performance of machined surfaces. Fatigue & Fracture of Engineering Materials & Structures, 14 (1991), pp. 329-336.
[17] ZHANG, P.; LINDEMANN, J.: Influence of shot peening on high cycle fatigue properties of the high-strength wrought alloy AZ80. Scripta Materialia, 52 (2005), pp. 485-490.

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# Conclusion

Conclusion

It also increases the surface roughness and erosion.

Due to overpeening effect, the treated specimens had shown lower fatigue strength than the original specimens.

The increase in hardness is not possible without a corresponding increase in surface roughness.

Multiple passes treatment results in increase of hardness and residual stresses.

# Outlook

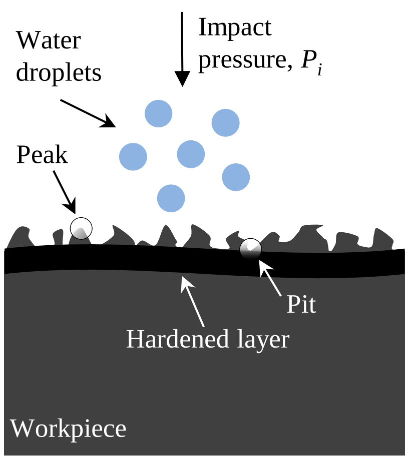
Multiple passes treatment can be used with a combination of the effect of WJP and smoothening action

How to increase the hardness without increasing the roughness?

Outlook

Multiple passes treatment is applied in steps

Initial steps: peening action
Later steps: smoothening action



# End of presentation

**“The more we know, the more we realize how little we know…”**

**Thank you very much for your kind attention!**